



Concurrent Performance of Gunner's and Robotic Operator's Tasks in a Simulated Mounted Combat System Environment

by Jessie Y.C. Chen and Carla Joyner

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| 14. ABSTRACT We simulated a Mounted Combat System (MCS) environment and conducted an experiment to examine the workload and performance of the combined position of gunner and robotic operator. Results showed that gunner's target detection performance degraded significantly when s/he had to concurrently monitor, manage, or teleoperate an unmanned ground vehicle compared to the baseline condition (gunnery task only). For the robotic tasks, participants detected significantly fewer targets when their robotic asset was semi-autonomous instead of teleoperated. The effects of individual difference factors such as spatial ability and perceived attentional control on the performance measures were also examined. | | | | | |
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1. Introduction

1.1 Purpose

The goal of this research was to examine if gunners in a Future Combat System (FCS) vehicle such as the Mounted Combat System (MCS) were able to effectively maintain local security (i.e., perform their gunners' tasks) while managing their unmanned assets. According to Mitchell (2005), which examined workload for MCS crew members using human performance modeling, the gunner is the most viable option for controlling robotic assets, compared to the other two positions (i.e., commander and driver). This current research examined if the gunner could effectively detect targets in his or her immediate environment while operating robotic assets in a remote environment.

1.2 Background

Past research in dual task performance suggests that operators may encounter difficulties when both tasks involve focal vision (Horrey & Wickens, 2004). Horrey and Wickens (2004) demonstrated that participants could not effectively detect road hazards while operating in-vehicle devices. Additionally, research about visual performance demonstrated that as the size of the search set increased, performance degraded in terms of speed, accuracy, or both (Scanlan, 1977). Murray (1994) showed that as the number of monitored displays increased, operators' reaction time for their target search tasks also increased linearly. In fact, reaction time almost doubled when the number of displays increased from 1 to 2 and from 2 to 3 (a slope of 1.94 was obtained).

According to Wickens, Dixon, and Chang (2003), visual angle separation larger than about 6.4 to 7.5 degrees may degrade event monitoring response time. In the case of concurrent performance of a gunner's and robotic operator's tasks, performance was expected to be worse than when the operator only had to perform one task since concurrent tasks involved more displays to visually scan. The gunner's task performance was expected to further degrade when the robotic tasks became more challenging (i.e., when more than mere monitoring was needed), for example, when robots needed teleoperation and/or when the operator needed to use the user interface to perform some tasks (e.g., putting targets on the map, labeling the targets, sending spot reports, etc.).

In addition, research has shown that increased mental workload could reduce the size of operator's visual field (Rantanen & Goldberg, 1999). It was expected that the reduced visual field would have a significant impact on the operator's gunnery task performance (i.e., target detection in his immediate environment).

Finally, signal-to-noise ratios (SNRs) were expected to impact an operator's performance (Wickens, 1992). As visual noise increased in the gunner's immediate environment or in the remote environment where the robots were located, the gunner's target detection performance was expected to degrade.

Participants' robotic task performance is expected to differ, depending on the type of asset available and the type of task they are asked to perform. Chen, Durlach, Sloan, and Bowens (2005) demonstrated that participants' target detection was significantly lower when they had to teleoperate the unmanned ground vehicle (UGV) as compared to when the UGV was semi-autonomous. Chen et al. suggested that maybe participants' teleoperation (i.e., driving the robot) negatively affected their target detection performance. Luck, Allender, and Russell (2006) reported that robotic operators' situational awareness (SA) was better when the small UGV had a higher level of automation. Luck et al. suggested that the attention on (manual) robotic control might have distracted the operators from focusing on the vehicle's location, which was the study's measure of SA. Dixon, Wickens, and Chang (2003) also reported that pilots found more targets when their unmanned aerial vehicle(s) were autonomous than when they were teleoperated.

1.3 Current Study

In this study, we simulated an MCS environment and conducted an experiment to examine the workload and performance of the combined position of gunner and robotic operator. In one condition (Gunner Baseline), participants had to perform the gunnery tasks only (i.e., target detection and engagement); in the other three conditions, they had to monitor or manage a UGV via the robotic operator control unit (OCU) while simultaneously performing their gunner's tasks. In one of the three concurrent task conditions (Monitor condition), participants only had to monitor the UGV via the video feed for targets; in the second condition (UGV condition), they had to actively manage the semi-autonomous UGV as well as monitor its video feed; in the third condition (Teleop condition), they had to teleoperate the UGV and monitor its video feed. Visual density levels (i.e., density of targets) were manipulated in the remote environment of the UGV and Teleop conditions so their effects on gunner's performance could be examined.

Participants also had to concurrently perform a tertiary communication task, which simulated gunner's communication with fellow crew members in the vehicle. Richard, Wright, Ee, Prime, Shimizu, and Vavrik (2002) found that participants' change detection was negatively affected by a concurrent auditory task. More specifically, participants' reaction times were slower and visual scanning was less effective. In the current study, we expected the concurrent communication to have a similar negative effect on participants' target detection performance. Although we did not manipulate the communication task as a variable, we tried to examine if participants with higher attentional control could perform their tasks more effectively than those with lower attentional control in our simulated multi-tasking environment. Schumacher et al. (2001) demonstrated that some participants were more effective in concurrently performing a visual task and an auditory task but did not examine what individual difference factor(s) contributed to that time-sharing effectiveness.

Finally, the relationship between participants' spatial ability (SpA) and their task performance was examined. According to Chen et al. (2005), those with higher SpA performed target detection tasks using robotic assets more effectively than those with lower SpA. In the current study, two different types of spatial tests were employed. It was expected that those with higher SpA test scores would perform their robotic tasks better.

2. Method

2.1 Participants

A total of 20 students (3 females and 17 males) was recruited from the University of Central Florida and participated in the study. The ages of the participants ranged from 18 to 45 ($M = 20.8$, $SD = 3.2$). Participants were compensated \$40 and were given class credit for their participation in the experiment.

2.2 Apparatus

2.2.1 Simulators

The experiment was conducted with a tactical control unit (TCU) developed by the U.S. Army Research Laboratory's (ARL's) Robotics Collaborative Technology Alliance (RCTA) for the robotic control tasks. The gunnery component was implemented with an additional screen and controls to simulate the out-the-window (OTW) view and line-of-sight (LOS) and beyond-line-of-sight (BLOS) firing capabilities.

The RCTA TCU is a one-person crew station from which the operator can control several simulated robotic assets, which can perform tasks semi-autonomously or be teleoperated (see figure 1). The operator switched operation modes and display modes through the use of a 19-inch touch-screen display. A joystick was used to manipulate the direction in which the unmanned vehicles moved when in Teleop mode. The UGV simulated in our study is the eXperimental unmanned vehicle (XUV) developed by ARL. The simulation program used in this study was rSAF, which is a version of OneSAF (one semi-automated force) for robotics simulation.

The gunnery component consisted of a monitor and a joystick (see figure 2). The interface consists of a 15-inch flat panel monitor and a joystick. Participants used the joystick to rotate the sensors 360 degrees, zoom in and out, switch between firing modes, and engage targets. For engaging BLOS targets, the participants need to receive authorization from the vehicle commander (i.e., the experimenter), align their aim with the direction of the target (the line would turn red when it was aiming at the target), and then fire.



Figure 1. User interface of RCTA TCU.



Figure 2. TCU (left) and gunnery station (gunner's OTW view) (right).

Cognitive tests were administered concurrently with the experimental sessions. The questions included simple military-related reasoning tests and simple memory tests. The inclusion of these cognitive tasks was for simulating an environment where the gunner was communicating with fellow crew members in the vehicle. For the reasoning tests, there were questions such as “if the enemy is to our left, and our UGV is to our right, what direction is the enemy to the UGV?” For the memory tests, the participants were asked to repeat some short statements or keep track of three radio call signs (e.g., Bravo 83) and they had to report to the experimenter whether the call signs they heard were one of those they were tracking. Test questions were delivered by a synthetic speech program, DECTalk¹.

The questions were pre-recorded by a male speaker and presented at the rate of one question approximately every 33 seconds.

2.2.2 Questionnaires and Tests

A demographics questionnaire was administered at the beginning of the training session (appendix A).

A questionnaire about attentional control (appendix B) (Derryberry & Reed, 2002) was used to evaluate participants’ perceived attentional control (PAC). The attentional control survey consists of 21 items and measures attention focus and shifting. The Cube Comparison Test (CCT) (Educational Testing Service, 2005) and the Spatial Orientation Test (SOT) were used to assess participants’ SpA. The CCT required participants to compare in 3 minutes, 21 pairs of six-sided cubes and determine if the rotated cubes were the same or different. The SOT, constructed by Dr. Paula Durlach of the U.S. Army Research Institute, is modeled after the cardinal direction test developed by Gugerty and his colleagues (Gugerty & Brooks, 2004) and is a computerized test consisting of a brief training segment and 32 test questions. Both accuracy and response time were automatically captured by the program. Participants’ perceived workload was evaluated via the National Aeronautics and Space Administration task load index (NASA-TLX) questionnaire (appendix C) (Hart & Staveland, 1988). The NASA-TLX is a self-reported questionnaire of perceived demands in nine areas: mental, physical, temporal, effort (mental and physical), frustration, performance, visual, cognitive, and psychomotor. Participants were asked to evaluate their perceived workload level in these areas on 10-point scales.

The Simulator Sickness Questionnaire (SSQ) (see appendix D) was used to evaluate participants’ simulator sickness symptoms (Kennedy, Lane, Berbaum, & Lilienthal, 1993). The SSQ consists of a checklist of 16 symptoms. Each symptom is related in terms of degrees of severity (none, slight, moderate, severe). A total severity (TS) score can be derived by a weighted scoring procedure and reflects overall discomfort level.

¹DECTalk is a registered trademark of Digital Equipment Corporation.

Finally, a usability questionnaire was constructed (see appendix E), based on the one used in the Unmanned Combat Demonstration (UCD) study, since the test bed used in our study was modeled after the crew station investigated in the UCD study (Kamsickas, 2003). Specifically, the questionnaire included the following sections: asset summary; reconnaissance, surveillance, and target acquisition (RSTA); map display; teleoperation; reporting, and general usability of the TCU. Participants indicated their level of agreement with the items using 7-point numerical scales. Participants were also given an opportunity to provide comments to support or clarify their numerical responses. The comments, in addition to the numerical responses, provided the researchers with further insight as to the participants' opinions about the crew station.

2.3 Experimental Design

The overall design of the study is a repeated measures design. There were six conditions:

- Gunnery Baseline (Gunner Baseline)
- Concurrent task conditions:
 - Monitor: Gunnery + Monitoring 1 Semi-autonomous UGV (*Monitor*)
 - Gunnery + Monitoring + Control of 1 Semi-autonomous UGV
 - Low Density (*UGV-Low*)
 - High Density (*UGV-High*)
 - Gunnery + Monitoring + Teleoperating UGV
 - Low Density (*Teleop-Low*)
 - High Density (*Teleop-High*)

Target density levels were manipulated in the UGV and Teleop conditions. In these conditions, ratios of target versus noise (i.e., neutral entities such as civilians and civilian vehicles) were manipulated. In the high density areas, the SNR was 1:3; in the low density areas, the ratio was 1:1.

For the purpose of comparing participants' robotic control task performance between the single-task and concurrent-task conditions, we added a UGV Baseline condition to half of the participants and a Teleop Baseline to the other half of the participants. In these two conditions, they did not have to perform the gunnery tasks and only had to simultaneously perform the robotic control tasks and the communication tasks.

2.4 Procedure

After being briefed about the purpose of the study, the tasks for the experiment, and any risks involved, participants read and signed a consent form. They then answered the attentional control survey and were administered the SpA tests (i.e., the CCT and the SOT). After these tests, participants received training, which lasted approximately 2 hours. Training was self-

paced and was delivered by PowerPoint² slides showing the elements of the TCU, steps for completing various tasks, several mini-exercises for practicing the steps, and two exercises for performing the robotic control tasks (one for practicing the Teleoperation task and one for practice of the UGV control tasks). After the tutorial on TCU, participants were trained in the gunnery tasks and completed an exercise including LOS and BLOS firing procedures. After the participants were familiar with the gunnery tasks, they completed one final exercise in which they performed the gunnery tasks and the robotic control tasks at the same time. At this point, all tutorial materials and information were removed and the participants had to be able to perform all these tasks on their own. After this final exercise, the experimenter determined if the participant needed any further practice on the robotic control tasks or gunnery tasks and provided some further training and exercises if necessary. Participants had to demonstrate that they could recall all the steps for performing the tasks without any help.

The experimental session took place on a different day but within a week of the training session. Participants' tasks were to use their robotic assets to locate targets in the remote environment (mixture of enemy tanks and dismounted Soldiers) and targets in their immediate (i.e., MCS) environment. There were 10 targets in each environment. The MCS was simulated as traveling along a designated route. They did this six times (i.e., six experimental sessions, each lasting approximately 15 minutes), and the order of experimental conditions was counterbalanced across participants.

For the Gunner Baseline, the operator performed only gunnery tasks (i.e., target detection and engagement). In the remaining concurrent task conditions, participants monitored the screens which simulated the OTW views and engaged targets as they were detected while performing the robotic tasks at the same time. Some of the targets in the immediate environment were BLOS. Participants needed to conduct BLOS fires when those targets were detected by the robotic assets. There were three concurrent task conditions: Monitor, UGV, and Teleop. The Monitor condition required the operator to monitor the video feed as the UGV traveled and report any targets detected (note: only human targets were used in the Monitor condition). The UGV conditions required the operator to monitor the video feed as the UGV traveled, examine still images generated from the reconnaissance scans (i.e., RSTA scans), which were enabled by the aided target recognition (ATR) capabilities, and detect targets. The Teleop conditions required the operator to manually manipulate and drive the UGV along a predetermined route using the TCU to detect targets. In the UGV and Teleop conditions, upon detecting a target, participants needed to place the target on the map, label the target, and then send a spot report. A list of robotic tasks for the UGV and Teleop conditions is presented in table 1.

²PowerPoint is a trademark of Microsoft Corporation.

Table 1. Robotic tasks for the UGV and teleop conditions.

| Condition | UGV | Teleop |
|-----------|---------------------------------|----------------------------|
| Tasks | Identify target or neutral | Identify target or neutral |
| | Verbally report neutrals | Verbally report neutrals |
| | Queue target (i.e., add to map) | Switch to map display |
| | Switch to map display | Add target to the map |
| | Label target | Label target |
| | Submit spot report | Submit spot report |

There were civilians and civilian vehicles in the simulated environment to increase the visual noise for the target detection tasks. In the remote environment, there were high density areas and low density areas. In the high density areas, the SNR was 1:3; in the low density areas, the ratio was 1:1. In the immediate environment, the SNR was constant throughout the route.

While the participants were performing their gunnery and/or robotic control tasks, they had to perform the communication tasks by answering questions delivered to them via a synthetic speech program, DECtalk.

Half of the participants also completed the UGV Baseline condition and the other half Teleop Baseline condition, in which they did not have to perform the gunnery tasks concurrently. Their only tasks were robotic and communication tasks. The UGV Baseline and Teleop Baseline conditions were completed right after their respective concurrent task conditions (i.e., UGV and Teleop). These two robotic baseline conditions allowed us to examine performance degradation in robotic tasks associated with concurrent task conditions (i.e., when the operator had to perform both the gunnery and the robotic tasks). There were 2-minute breaks between experimental sessions.

Participants assessed their workload using the NASA-TLX after they completed each experimental session, except for the UGV and Teleop conditions. They only answered the questionnaire after they completed both the high and low visual density conditions. At the conclusion of all scenarios, participants were administered the SSQ, used to evaluate the severity of their simulator sickness symptoms. The participants also completed a usability questionnaire regarding the TCU at the end of the experimental session.

2.5 Measures

The dependent measures include mission performance (i.e., number of targets detected in the remote environment using the robotic assets and number of enemy targets detected in the immediate environment), communication task performance, and perceived workload.

3. Results

3.1 Target Detection Performance

3.1.1 Gunnery Tasks

Table 2 lists several measures relating to enemy target detection. Correlations between participants' gunnery task performance and their attentional control, cube test, and SOT scores were first evaluated. The SOT scores were found to be the most accurate predictor of participants' gunnery performance, with Gunner Baseline, Monitor, and Teleop conditions being significant (r 's = 0.408, 0.506, 0.55, all p 's < 0.05). Participants were then designated as high spatial ability or low spatial ability, based on their SOT scores (median split). A mixed analysis of variance (ANOVA) was performed to examine the effects of the concurrent robotic control tasks on the gunnery task performance, with the Asset condition (Gunner Baseline, Monitor, UGV-Low, UGV-High, Teleop-Low, and Teleop-High) being the within-subject factor and SpA (SOT score) as the between-subject factor. The analysis revealed that the Asset condition significantly affected number of targets detected, $F(5, 15) = 7.32$, $p < 0.001$, with Gunner Baseline being the highest and Teleop-High being the lowest (figure 3). *Post hoc* tests (Least Significant Difference or LSD) showed that target detection in Gunner Baseline was significantly higher than every condition except Monitor. Monitor was significantly higher than all the UGV and Teleop conditions. Teleop-High was significantly lower than both UGV conditions. Participants with higher SpA had significantly higher gunnery task performance than did those with lower SpA, $F(1, 18) = 8.76$, $p < 0.005$ (figure 4).

Table 2. Mean proportion of targets detected (standard deviations are shown in parentheses).

| Measures | Condition | | | | | |
|--|----------------------------|------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| | Gunner Baseline | Monitor | UGV-Low | UGV-High | Teleop-Low | Teleop-High |
| Gunnery Task (Enemy targets detected) | .69 ^a (.174) | .645 ^a (.196) | .505 ^b (.191) | .495 ^b (.176) | .485 ^b (.228) | .405 ^c (.161) |
| Robotic Task (human targets only) | NA | .6300 ^a (.138) | .5983 ^b (.1441) | .4653 ^c (.2063) | .7052 ^a (.2167) | .5754 ^a (.2243) |
| Robotic Task (vehicle targets only) | NA | NA | .8917 ^a (.1271) | .8506 ^a (.1329) | .9167 ^a (.1239) | .8822 ^a (.1433) |

^aNote: Statistics with the same superscript are not significantly different from one another

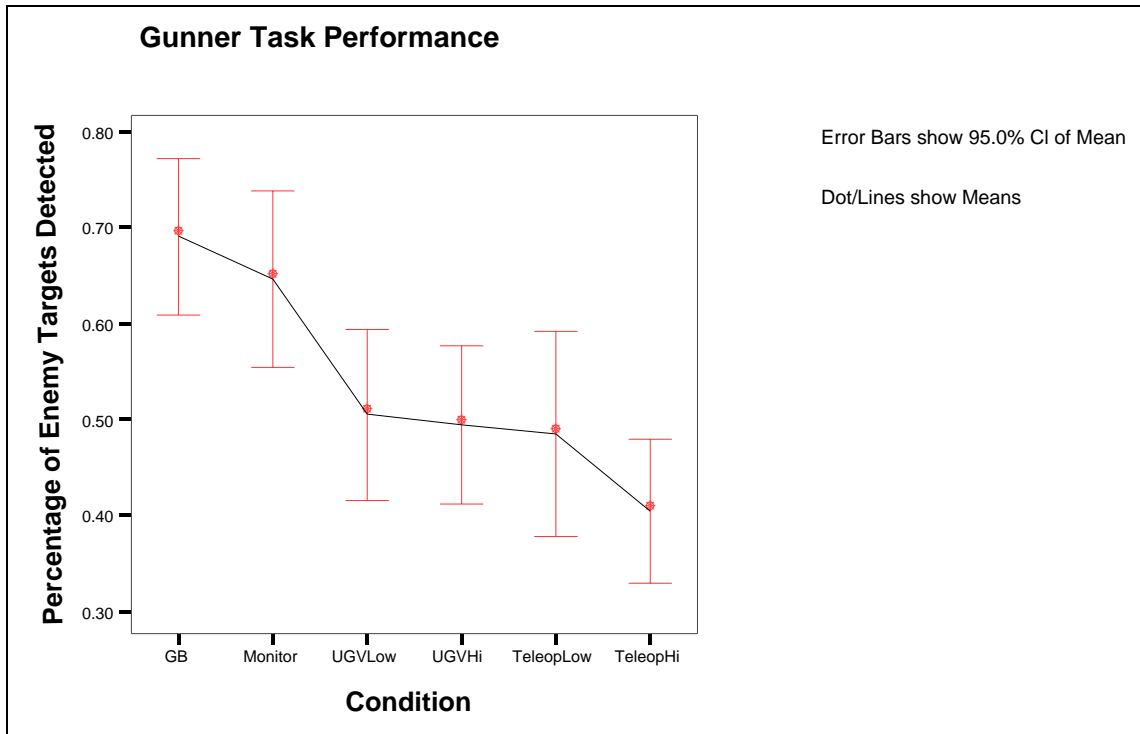


Figure 3. Gunner's enemy target detection performance.



Figure 4. Effects of SpA (SOT) on gunner's enemy target detection performance.

3.1.2 Robotic Tasks

None of the individual difference factors (i.e., PAC and SpA measured by the SOT and the CCT) were found to consistently correlate with participants' robotic task performance. SOT scores correlated significantly with robotic task performance in the UGV condition, $r = .489$ ($p = 0.014$) but not in other conditions. We also examined participants' speed in performing the SOT and found that it correlated negatively with robotic task performance in the Teleop condition, $r = -0.463$ ($p = 0.02$).

Two repeated measures ANOVAs were performed to compare participants' target detection performance on the robotic tasks, one for the human targets and the other for the vehicle targets. The UGV-Low and UGV-High conditions were combined as the UGV condition, and the Teleop-Low and Teleop-High conditions were combined as the Teleop condition. The first analysis showed there were significant differences among the Monitor, UGV, and Teleop conditions in human target detection, $F(2, 18) = 4.794$, $p < 0.05$, with UGV being the lowest (see figure 5). *Post hoc* tests (LSD) showed that differences between Monitor and UGV and between Teleop and UGV were significant. The second analysis examined the difference between the UGV and the Teleop conditions in vehicle target detection and the difference was not significant.

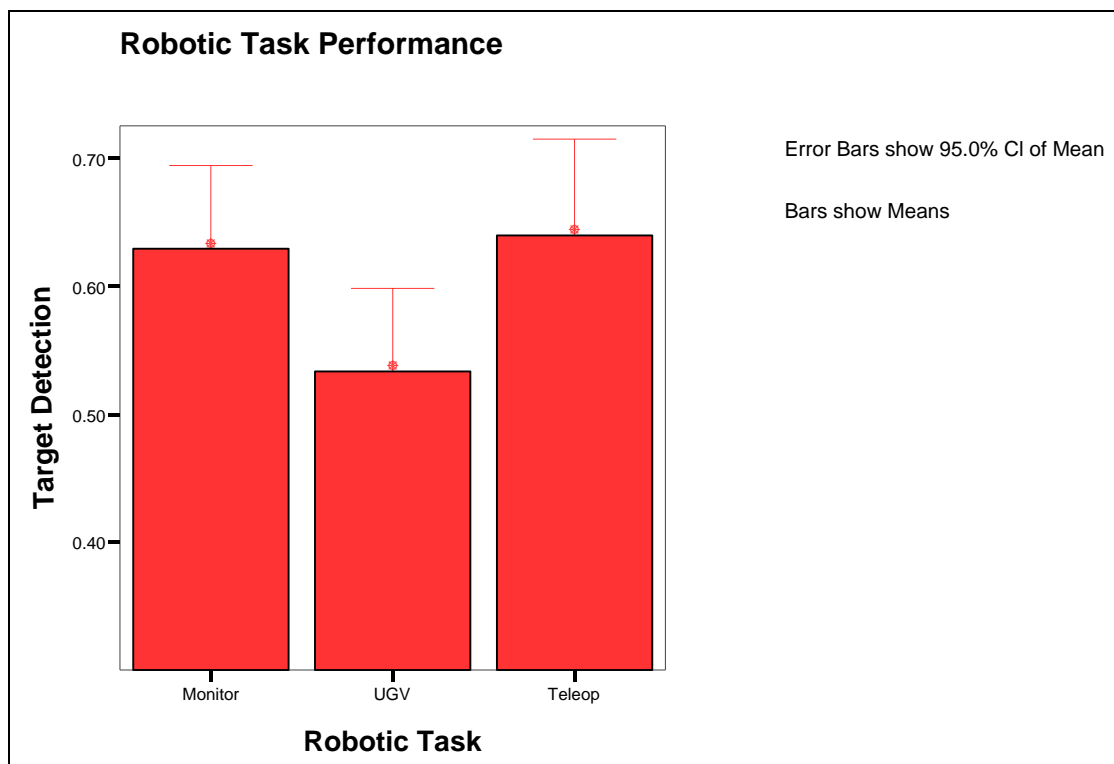


Figure 5. Robotic task performance.

To further examine why the Teleop condition produced better target detection rates than the UGV condition, which conflicted with the findings in Chen et al. (2005), we compared the amounts of targets detected along the route and targets detected within RSTA areas for the UGV

and Teleop conditions. A 2 x 2 repeated measures ANOVA was performed with Asset condition (UGV versus Teleop) and Target Location (Route versus RSTA) as the factors. The analysis revealed that both effects were significant: Asset, $F(1, 38) = 5.75, p = 0.019$; Location $F(1, 38) = 18.01, p < 0.0001$. *Post hoc* tests showed that the largest difference in targets detected was along the route, with UGV having a 35% and Teleop 51% target detection rate.

Half of the participants also completed the UGV Baseline condition and the other half Teleop Baseline condition so we could compare if participants' target detection performance degraded when they had to perform the gunnery task concurrently. Results showed that when participants only had to operate the UGV, their overall target detection rate (including both human and vehicle targets) was 80%; when they had to concurrently operate the UGV while performing the gunner's tasks (i.e., UGV condition), their target detection using the UGV dropped to 67% (difference marginally significant). These results are presented graphically in figure 6.

The effect of visual density was examined with a 2 x 2 repeated measures ANOVA with the Asset (UGV versus Teleop) and Visual Density (High versus Low) as the factors. The effect of visual density was significant, $F(1, 38) = 7.875, p = 0.008$, with lower target detection performance associated with higher visual density (figure 7). None of the individual difference factors was significant.

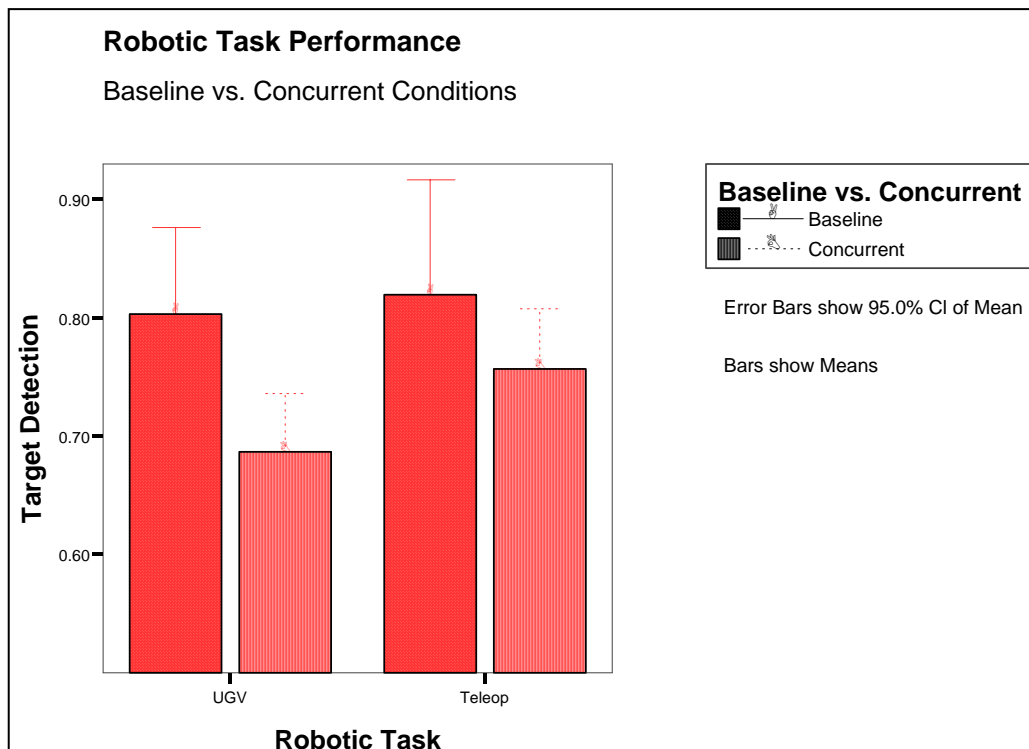


Figure 6. Comparisons between robotic-baseline and robotic-concurrent.

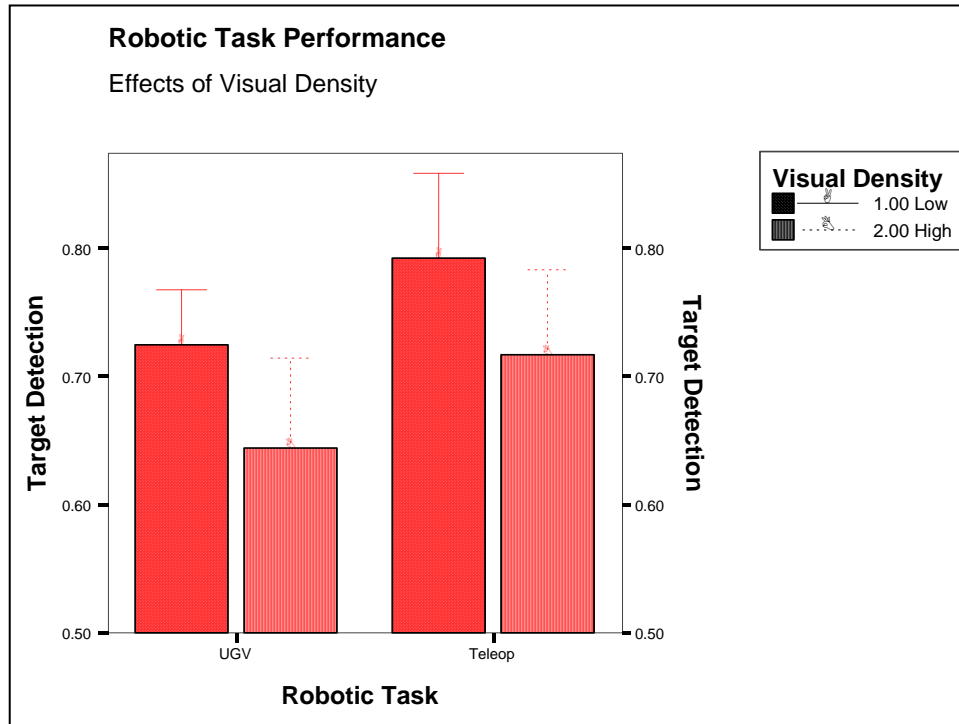


Figure 7. Effects of visual density on robotic task performance.

3.2 Communication Task Performance

The differences among the four conditions were significant, $F(3, 16) = 6.574, p < 0.005$, with the Gunner Baseline and Monitor conditions being higher than the UGV and Teleop conditions. Participants' PAC was identified by their attentional control survey scores. Attentional control scores were found to be positively correlated with the communication task performance in the Teleop conditions, $r = 0.476$ ($p = 0.023$). For the UGV condition, the correlation was marginally significant $r = 0.385$ ($p = 0.057$). Results are graphically presented in figure 8.

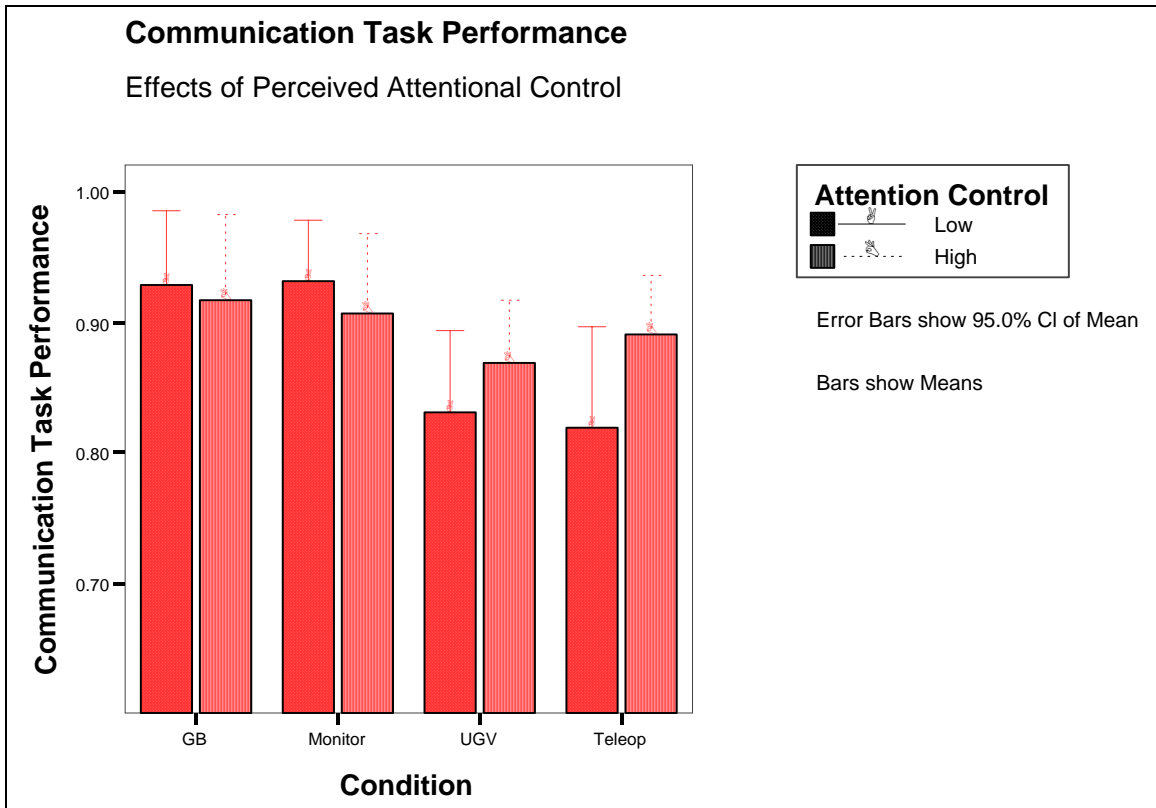


Figure 8. Communication task performance.

3.3 Perceived Workload

Unweighted ratings of the scales of the NASA-TLX were used for this analysis. Participants' self-assessment of workload was significantly affected by Asset condition, $F(3, 17) = 65.102$, $p < 0.0001$. The perceived workload was highest in the Teleop condition ($M = 43.025$) and lowest in the Gunner Baseline condition ($M = 22.35$). All pairwise comparisons were significant. Results are presented graphically in figure 9. Correlations between participants' perceived workload and their PAC, CCT, and SOT scores were evaluated. The correlations between PAC and workload were all negative (those with higher PAC had lower perceived workload than did those with lower scores), but only Teleop reached significance, $r = -0.516$ ($p = 0.012$). The correlations between CCT scores and workload were all positive (those with higher CCT scores had *higher* perceived workload than did those with lower scores), with UGV and Teleop reached significance, $r = 0.587$ ($p = 0.003$) and $r = 0.484$ ($p = 0.015$), respectively. The correlations between SOT scores and workload were less consistent, with only UGV reached significance, $r = 0.441$ ($p = 0.026$). Correlations between participants' reaction times for the SOT and their perceived workload were also evaluated. The correlations were also negative (those who were faster had *higher* perceived workload than did those with lower scores), but none reached significance.

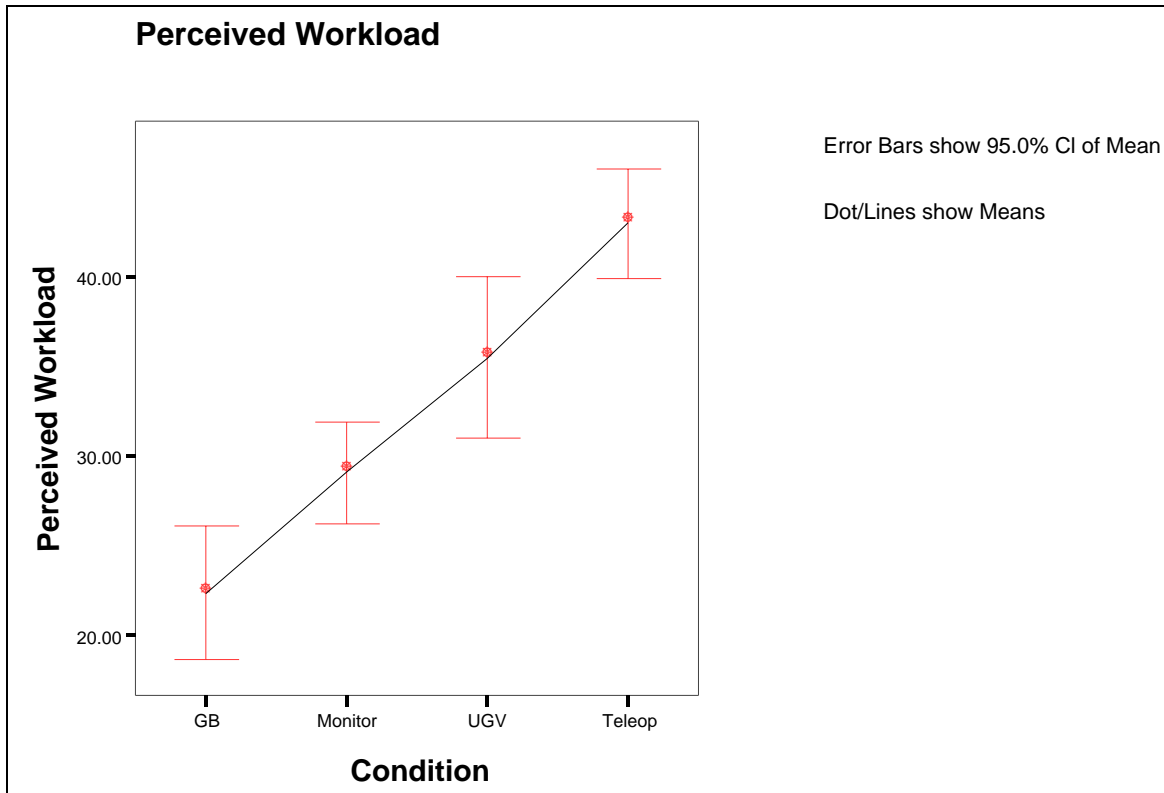


Figure 9. Perceived workload.

3.4 Simulator Sickness

Participants' simulator sickness scores (SSQ: three sub-scales and the total severity score [TSS]) were calculated on the basis of formulae in Kennedy et al. (1993) (see appendix F for the scoring procedure). The average TSS was 29.36 ($SD = 24.06$). Further examination of the sub-scale data indicated that the oculomotor aspect significantly contributed to the elevated TSS. In order to evaluate the relationship between simulator sickness and performance and perceived workload, we calculated aggregated workload ratings, gunnery performance, and robotic task performance by averaging the data across conditions. We found that there was a significant correlation between TSS and workload, $r = 0.379$ ($p = 0.05$). Correlations between TSS and the two aggregated performance measures were both negative, as expected, but were not significant. Correlations between participants' SSQ and their SOT, CCT, and PAC scores were also evaluated. Only the correlations between SSQ and attentional control were consistent and mostly significant, $r = -0.612$, $r = -0.425$, $r = -0.432$ ($p = 0.003$, $p = 0.035$, $p = 0.032$) for nausea, oculomotor, and TSS, respectively. SSQ for higher versus lower attentional control participants are presented in table 3 and figure 10.

Table 3. Simulator sickness scores (standard deviations are shown in parentheses).

| Participants | Nausea | Oculomotor | Disorientation | TSS |
|--------------------------|------------------|------------------|------------------|------------------|
| Low Attentional Control | 29.68 (24.99) | 38.74 (31.13) | 24.75 (33.94) | 37.4 (31.95) |
| High Attentional Control | 14.31 (11.24) | 28.8 (13.75) | 15.31 (21.21) | 23.94 (13.45) |

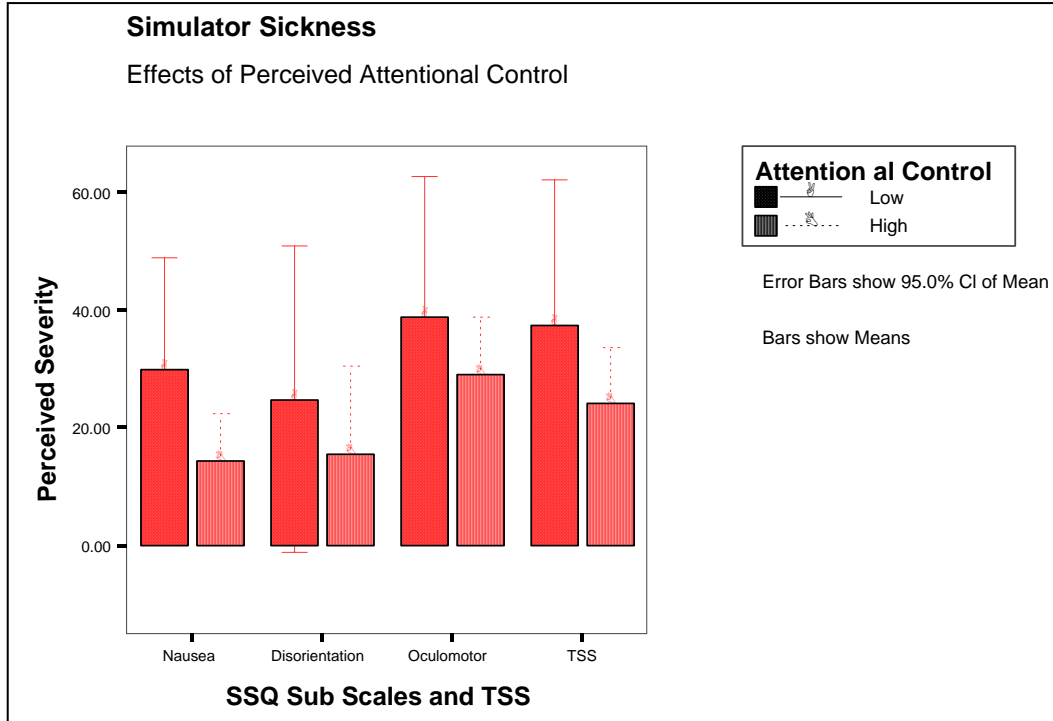


Figure 10. Simulator sickness and effects of PAC.

3.5 Usability Questionnaire

Participants' ratings and their comments are presented in appendix G. Generally, the TCU was perceived to be user friendly. However, a number of participants suggested that it required too many steps to complete some simple tasks and they needed to go to different screens to complete those steps (e.g., putting targets on the map, labeling the targets, and sending spot reports). While they were completing those steps, they could not effectively monitor the gunnery station. If these steps can be more consolidated and centralized, this part of the robotic task would not require as much visual attention as it currently does.

4. Discussion

In this study, we simulated an MCS environment and performed an experiment to examine the workload and performance of the combined position of gunner and robotic operator. Results showed that gunner's target detection performance degraded significantly when s/he had to concurrently monitor, manage, or teleoperate a UGV. The gunner's performance in the three concurrent task conditions was significantly different from one another, with the Monitor condition being the highest and Teleop condition being the lowest. Participants' SpA as measured by their SOT scores was found to be an accurate predictor of their gunnery performance. These results suggest that, if it is necessary for the gunner to concurrently access information from the robotic assets, the robotic tasks should be limited to activities such as monitoring. If excessive manipulation of the user interface is required as in the UGV and Teleop conditions, gunnery performance will be significantly affected. When selecting personnel for these tasks, it might be beneficial to take into account their SpA. Thomas and Wickens (2004) showed that there were individual differences in scanning effectiveness and its associated target detection performance. However, Thomas and Wickens (2004) did not examine the characteristics of those participants who had more effective scanning strategies. Results of the current study suggest that spatial tests such as the SOT might be useful in examining individual differences in scanning behavior and target detection performance. Further research should also examine the difference between the SOT and the CCT. Based on the results of the current study, it appears that these two tests tapped different aspects of SpA. Some cognitive modeling work done by ARL researchers suggested that the CCT may reflect ability more associated with feature comparison than with spatial rotation (Kelley, Wiley, & Lee, 2000). Verbal protocol obtained from research participants in Kelley, Wiley, and Lee (2000) indicated that participants used a variety of problem-solving strategies for their spatial rotation test instead of mentally rotating the images.

For the robotic tasks, there were significant differences among the Monitor, UGV, and Teleop conditions in human target detection performance, with the UGV being the lowest (only 53% were detected). The inferior performance associated with the semi-autonomous UGV seemed to reflect participant's over-reliance on the ATR capabilities and failure to detect more targets along the route that were not detected by the ATR. In contrast, in Chen et al. (2005), participants had the lowest target detection using the Teleop. However, in Chen et al.'s (2005) UGV condition, the ATR capabilities were not available. Results of the current study are consistent with automation research that operators may develop over-reliance on the automatic system and this complacency may negatively affect their task performance (Parasuraman, Molloy, & Singh, 1993). Thomas and Wickens (2000) showed that when participants had access to information gathered from automatically panning cameras, they tended to prematurely close the automatic panning feature before finishing examining the entire environment. On the other hand, participants manually

panning the cameras had significantly higher target detection performance, which indicated more adequate panning. It is worth noting that these findings along with the results of the current study do not necessarily suggest that manual manipulation of sensor devices be used instead of ATR or auto-panning devices. However, the issue of over-reliance on these automatic capabilities needs to be taken into account when one is designing the user interface where these features are one of the components.

When participants only had to operate the UGV (i.e., UGV Baseline), their overall target detection rate was 80%; when they had to concurrently operate the UGV and perform the gunner's tasks (i.e., UGV condition), their target detection using the UGV dropped to 67%. It also appears that the performance difference between UGV and Teleop widened in the concurrent task conditions compared with the single-task (baseline) conditions. In other words, the UGV Baseline and Teleop Baseline were at similar levels but UGV-Concurrent was significantly lower than Teleop-Concurrent. These results suggest that as operator's tasks become more challenging (i.e., concurrent conditions), s/he may rely more on the ATR capabilities to relieve the workload if they are available. However, the over-reliance on the ATR capabilities may result in overall performance degradation as discussed in the previous paragraph.

None of the individual difference factors was found to significantly correlate with participants' robotic task performance. The lack of correlation between SpA and robotic task performance was unexpected. Chen et al. (2005) showed that those with higher SpA (as measured by the CCT) had significantly higher performance in their target detection task using the UGV. Further research is needed to examine the relationship between SpA and robotic task performance.

Participants' communication task performance degraded when their robotic tasks became more challenging (i.e., UGV and Teleop conditions). It is interesting to note that participants appeared to be able to perform their communication task at similar levels in the Gunner Baseline and Monitor conditions. This suggests that in the Monitor condition, participants had sufficient cognitive resources left to perform the communication tasks. Participants with higher PAC (measured by a self-assessment survey) performed better on a concurrent communication task, although they performed at a similar level on their gunnery and robotic control tasks as those with lower PAC. These results suggest that participants devoted most of their attention resources to the gunnery and robotic tasks, and only those with higher attention allocation skills could more successfully perform the tertiary communication tasks. Since communication will be a critical part in the task environment, these results may have important implications for personnel selection for the Army's future forces.

Participants' perceived workload increased almost linearly in order from the Gunner Baseline, Monitor, UGV and to the Teleop condition, and the differences among the four conditions were all statistically significant. These results are consistent with Schipani (2003), which evaluated robotic operator workload in a field setting. Although many of the ground robotic assets in the Army's FCS program will be semi-autonomous, it is very likely that teleoperation will be

required at times when the robotic assets encounter problems. The higher workload associated with teleoperation needs to be taken into account when one is designing the user interfaces for the FCS. Additionally, it appears that participants with higher SpA, although performing better on the tasks, did not perceive the tasks as less demanding. In fact, the correlations between participants' perceived workload and their CCT scores or SOT reaction times indicated that those with higher SpA (at least according to these two measures) actually perceived the tasks as *more* demanding. The correlations between participants' PAC and their workload were as expected. Those with higher PAC thought the tasks were less demanding. It is worth noting that only in the most challenging condition (i.e., Teleop) did the correlation reach significance. In other words, as the tasks became more difficult, the differences in the levels of perceived workload between those with higher and lower PAC appeared to widen. The relationships between workload and PAC and SpA need to be further investigated.

Participants seemed to experience fairly significant levels of simulator sickness, especially in the oculomotor area. The high demand of visual attention, particularly in the concurrent task conditions, may have contributed to the elevated levels of simulator sickness the participants experienced. It is worth noting that our entire experimental session only lasted about 1-1/2 hours. Any duration longer than this may induce even more severe sickness. Participants with lower PAC had significantly higher simulator sickness than did those with higher attentional control. It was reported that in the virtual environment, those who need to concentrate more tended to experience higher levels of simulator sickness (Regan, as cited in Kolasinski, 1995). The findings of the Regan study and the current study seem to suggest that those who are better at allocating their attentional resources may experience lower simulator sickness. Alternatively, those with lower PAC might pay more attention to (and be distracted by) their own bodily reaction (Jerome, personal communication, February 10, 2006). This increased awareness may have contributed to the elevated levels of simulator sickness. It is also possible that they were not experiencing more sickness but were simply more aware of the symptoms. More research in this area is needed to examine this relationship.

5. Conclusions

The findings of the current study suggest that in an FCS task environment such as the MCS, if it is necessary for the gunner to concurrently access information from the robotic assets, the robotic tasks should be limited to activities such as monitoring. If excessive manipulation of the user interface occurs as in the UGV and Teleop conditions, gunnery performance and communications with fellow crew members may be significantly affected. When selecting personnel for these tasks, it might be beneficial to take into account their SpA (SOT) and PAC. In the current study, those with higher SpA as measured by the SOT appeared to be better able to perform their gunnery tasks concurrently with the other two tasks. Those with higher PAC were more effective in

performing the communicating tasks concurrently with the tasks, especially when the robotic tasks needed more attention and manipulations. They also experienced a lower level of simulator sickness.

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Appendix A. Demographic Questionnaire

Participant # _____ Age _____ Major _____ Date _____ Gender _____

1. What is the highest level of education you have had?

Less than 4 yrs of college _____ Completed 4 yrs of college _____ Other _____

2. When did you use computers in your education? (*Circle all that apply*)

| | | |
|------------------|----------|-------------|
| Grade School | Jr. High | High School |
| Technical School | College | Did Not Use |

3. Where do you currently use a computer? (*Circle all that apply*)

Home _____ Work _____ Library _____ Other _____ Do Not Use _____

4. For each of the following questions, circle the response that best describes you.

How often do you:

Use a mouse? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use a joystick? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use a touch screen? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use icon-based programs/software? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use programs/software with pull-down menus? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use graphics/drawing features in software packages? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Use E-mail? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Operate a radio controlled vehicle (car, boat, or plane)? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

Play computer/video games? _____ Daily, Weekly, Monthly, Once every few months, Rarely, Never

5. Which type(s) of computer/video games do you most often play if you play at least once every few months?

6. Which of the following best describes your expertise with computer? (check $\sqrt{\quad}$ one)

_____ Novice

_____ Good with one type of software package (such as word processing or slides)

_____ Good with several software packages

_____ Can program in one language and use several software packages

_____ Can program in several languages and use several software packages

7. Are you in your usual state of health physically? YES NO

If NO, please briefly explain:

8. How many hours of sleep did you get last night? _____ hours

9. Do you have normal color vision? YES NO

10. Do you have prior military service? YES NO If Yes, how long _____

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Appendix B. Attentional Control Survey

For each of the following questions, circle the response that best describes you.

It is very hard for me to concentrate on a difficult task when there are noises around.
Almost never, Sometimes, Often, Always

When I need to concentrate and solve a problem, I have trouble focusing my attention.
Almost never, Sometimes, Often, Always

When I am working hard on something, I still get distracted by events around me.
Almost never, Sometimes, Often, Always

My concentration is good even if there is music in the room around me.
Almost never, Sometimes, Often, Always

When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.
Almost never, Sometimes, Often, Always

When I am reading or studying, I am easily distracted if there are people talking in the same room.
Almost never, Sometimes, Often, Always

When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
Almost never, Sometimes, Often, Always

I have a hard time concentrating when I'm excited about something.
Almost never, Sometimes, Often, Always

When concentrating, I ignore feelings of hunger or thirst. Almost never, Sometimes, Often, Always

I can quickly switch from one task to another. Almost never, Sometimes, Often, Always

It takes me a while to get really involved in a new task. Almost never, Sometimes, Often, Always

It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.
Almost never, Sometimes, Often, Always

I can become interested in a new topic very quickly when I need to.
Almost never, Sometimes, Often, Always

It is easy for me to read or write while I'm also talking on the phone.
Almost never, Sometimes, Often, Always

I have trouble carrying on two conversations at once. Almost never, Sometimes, Often, Always

I have a hard time coming up with new ideas quickly. Almost never, Sometimes, Often, Always

After being interrupted or distracted, I can easily shift my attention back to what I was doing before.
Almost never, Sometimes, Often, Always

When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
Almost never, Sometimes, Often, Always

It is easy for me to alternate between two different tasks. Almost never, Sometimes, Often, Always

It is hard for me to break from one way of thinking about something and look at it from another point of view.
Almost never, Sometimes, Often, Always

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Appendix C. NASA-TLX Questionnaire

Please rate your overall impression of demands imposed on you during the exercise.

1. Mental Demand: How much mental and perceptual activity was required (e.g., thinking, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

2. Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

3. Temporal Demand: How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

4. Level of Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

5. Level of Frustration: How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

6. Performance: How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

LOW |---|---|---|---|---|---|---|---|---| HIGH
1 2 3 4 5 6 7 8 9 10

7. Please mark the indicated loading that most closely matches the work performed by your visual, cognitive, and motor efforts on the task just completed.

Visual

LOW Load |---|---|---|---|---|---|---|---|---| HIGH Load
1 2 3 4 5 6 7 8 9 10

Cognitive

LOW Load |---|---|---|---|---|---|---|---|---| HIGH Load
1 2 3 4 5 6 7 8 9 10

Psychomotor (Relating to the physical activities associated with mental processes)

LOW Load |---|---|---|---|---|---|---|---|---| HIGH Load
1 2 3 4 5 6 7 8 9 10

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Appendix D. Simulator Sickness (Current Health Status) Questionnaire

ID _____

Time & Date _____

Instructions: Please indicate how you feel **right now** in the following areas, by **circling** the word that applies.

| | | | | | |
|-----|--------------------------|------|--------|----------|--------|
| 1. | General Discomfort | None | Slight | Moderate | Severe |
| 2. | Fatigue | None | Slight | Moderate | Severe |
| 3. | Headache | None | Slight | Moderate | Severe |
| 4. | Eye Strain | None | Slight | Moderate | Severe |
| 5. | Difficulty Focusing | None | Slight | Moderate | Severe |
| 6. | Increased Salivation | None | Slight | Moderate | Severe |
| 7. | Sweating | None | Slight | Moderate | Severe |
| 8. | Nausea | None | Slight | Moderate | Severe |
| 9. | Difficulty Concentrating | None | Slight | Moderate | Severe |
| 10. | Fullness of Head | None | Slight | Moderate | Severe |
| 11. | Blurred vision | None | Slight | Moderate | Severe |
| 12. | Dizzy (Eyes Open) | None | Slight | Moderate | Severe |
| 13. | Dizzy (Eyes Closed) | None | Slight | Moderate | Severe |
| 14. | Vertigo* | None | Slight | Moderate | Severe |
| 15. | Stomach Awareness** | None | Slight | Moderate | Severe |
| 16. | Burping | None | Slight | Moderate | Severe |

*Vertigo is a disordered state in which the person or his/her surroundings seem to whirl dizzily: giddiness.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Are there any other symptoms you are experiencing right now? If so, please describe the symptom(s) and rate its/their severity below. Use the other side if necessary.

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Appendix E. Usability Questionnaire

Instructions

Usability Survey

Participant #_____

This questionnaire is designed to elicit your reactions for the use of the OCU. Your responses will help us understand what aspects of the OCU you find inefficient or difficult to use. This questionnaire provides an opportunity to evaluate the usability of the system. We will use your responses to influence the design of the future OCU. To as great a degree as possible, think about all the tasks that you have performed with the OCU while you answer the questions.

Read each statement or question and indicate your response to the statement or question by circling the value you feel best gauges your answer to the question on the scale underneath it. If a statement does not apply, circle **N/A**. Use the space on the right to provide any comments that would help us improve the design of the crew station interface. Comments clarifying answers are extremely useful.

Asset Summary

- | | | Comments |
|--|---|----------|
| 1. There was adequate information displayed with regard to the state of the Unmanned Vehicles (UVs). | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |
| 2. The text on the Asset Summary screen was easy to read. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |
| 3. The information presented in the display was easy to interpret. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |
| 4. Gaining control of an UV was easy to do. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |
| 5. The Asset Summary display was easy to use. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |

Map Display

- | | | Comments |
|---|---|----------|
| 1. The button labels accurately represented the buttons' functionality. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |
| 2. The information presented on the mapping display was easy to read. | | |
| Strongly DISAGREE | --- --- --- --- --- --- Strongly AGREE | N/A |
| | 1 2 3 4 5 6 7 | |

| | | | |
|-----|---|-----|----------|
| 3. | The map resolution made it difficult for me to select a specific location. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 4. | It was easy to understand what the icons used on the map displays represented. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 5. | I was able to navigate the map effectively. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 6. | Icons representing different unmanned vehicles were easy to distinguish. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 7. | The map terrain features (roads, water, vegetation) were difficult to see. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 8. | The orientation of the unmanned vehicles is represented clearly. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 9. | The map was my main source of situation awareness. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 10. | Text on the map status display was easy to understand. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 11. | It was easy to modify the icons on the map. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 12. | Overall the mapping display was easy to use. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

RSTA

| | | | |
|----|--|-----|----------|
| 1. | The print/text used on the RSTA display was easy to read. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 2. | The layout of the RSTA screen made sense. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 3. | The video imagery for RSTA Scan from the XUVs is clear. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

| | | | |
|----|---|-----|----------|
| 4. | The RSTA display should contain additional information. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 5. | The button labels accurately represented their intended functions. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 6. | I would like to see more functionality added to the RSTA Scan. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 7. | This display made it easy to queue targets. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 8. | I was able to manipulate the RSTA images effectively. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

Teleoperation

| | | | |
|----|--|-----|----------|
| 1. | The streaming video was sufficient to allow me to teleoperate the XUV. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 2. | I used the map display while teleoperating an XUV to help me maintain the location of an XUV. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 3. | There was a significant time delay that made controlling the XUV difficult. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 4. | The button labels accurately represented the buttons' functionality. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 5. | I found the Teleoperation display easy to use to control XUVs. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

Reporting

| | | | |
|----|---|-----|----------|
| 1. | The button labels accurately represented the buttons' functionality. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

| | | | |
|----|--|-----|----------|
| 2. | Much of the information presented on the display was NOT helpful. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 3. | I sometimes felt 'lost' navigating the reporting display screens. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 4. | There was not enough information displayed on the reporting screen. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 5. | Composing a SPOT report was an easy task to accomplish. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 6. | Composing a SPOT report took too long to accomplish. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 7. | The entry fields for composing a SPOT report were found in the order I expected them to be. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 8. | Using the reporting display to compose reports was an easy process overall. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

General Usability- RCTA OCU

Definitions:

- A **screen** is defined as the physical object that may be handled.
- A **display** is the software image that is displayed on the screen.
- A **soft button** is a computer generated image of a button displayed on the screen

| | | | |
|----|---|-----|----------|
| 1. | The touchscreen buttons were large enough to use effectively. | | Comments |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 2. | The print/ text on the OCU soft buttons was clear, and easy to read. | | |
| | Strongly DISAGREE ---- ---- ---- ---- ---- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

| | | | |
|-----|---|-----|----------|
| 3. | It was easy to learn to use the basic features of the OCU. | | Comments |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 4. | There are <u>not</u> enough displays to accomplish the required tasks. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 5. | The point at which my finger touches is not identical to the point indicated by the touchscreen (there are parallax problems). | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 6. | Throughout the OCU, the same terminology is used to indicate the same information. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 7. | I sometimes feel "lost" when working with the OCU. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 8. | I had a hard time finding information I needed on the OCU. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 9. | It was easy to understand what the icons used on the OCU displays represented. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 10. | The OCU gives appropriate warning messages when I am about to make a serious mistake. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 11. | With the OCU, if I make a mistake I can correct it easily. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 12. | It is obvious which command button brings up the OCU display I need next. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 13. | Information is appropriately arranged on the OCU displays. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 14. | Color-coding on the OCU displays is helpful. | | |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |
| 15. | The symbols that were used were hard to learn. | | Comments |
| | Strongly DISAGREE --- --- --- --- --- --- Strongly AGREE | N/A | |
| | 1 2 3 4 5 6 7 | | |

16. Overall, I think the OCU was easy to learn.

Strongly DISAGREE |----|----|----|----|----|----| Strongly AGREE N/A
1 2 3 4 5 6 7

17. Overall, I think the OCU was easy to work with.

Strongly DISAGREE |----|----|----|----|----|----| Strongly AGREE N/A
1 2 3 4 5 6 7

Appendix F. Scoring Procedure for the SSQ

Symptoms scored 0 (None) - 3 (Severe)

Nausea (Raw) - Sum of General discomfort, increased salivation, sweating, nausea, diff concentrating, stomach awareness, burping

$$Nausea\ sub\ scale = Nausea\ (Raw) \times 9.54$$

Oculomotor - Sum of general discomfort, fatigue, headache, eye strain, diff focusing, diff concentrating, blurred vision

$$Oculomotor\ sub\ scale = Nausea\ (Raw) \times 7.58$$

Disorientation - Sum of diff focusing, nausea, fullness of head, blurred vision, dizzy (eyes open), dizzy (eyes closed), vertigo

$$Disorientation\ sub\ scale = Nausea\ (Raw) \times 13.92$$

$$TSS = [Nausea\ (Raw) + Oculomotor\ (Raw) + Disorientation\ (Raw)] \times 3.74$$

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| | |
|--|------|
| 21. The map was my main source of situation awareness. | 5.44 |
| 22. Text on the map status display was easy to understand. | 5.5 |
| 23. It was easy to modify the icons on the map. | 4.35 |
| Too many different screens to accomplish one task | |
| 24. Overall the mapping display was easy to use. | 5.75 |

RSTA

| | |
|---|----------------|
| 9. The print/text used on the RSTA display was easy to read. | Rating 5.83 |
| 10. The layout of the RSTA screen made sense. | 5.64 |
| After a little use, easy to comprehend | |
| Biggest difficulty JPEG artifact impeded target ID | |
| 11. The video imagery for RSTA Scan from the XUVs is clear. | 3.53 |
| Res wasn't very good, had to take multiple mosaics/pics to be sure | |
| 12. The RSTA display should contain additional information. | 4.33 |
| Which checkpoint you are at | |
| # of enemies queued so far | |
| Perhaps could add distance or thermal imaging | |
| 13. The button labels accurately represented their intended functions. | 5.3 |
| Some are similar in their labels but different in use (edit -> rename, lable) | |
| 14. I would like to see more functionality added to the RSTA Scan. | |
| Useful to have a list of labeled enemies, that way you can number them in order when you approach another enemy | 4.83 |
| Pretty good amount | |
| Useful to know if a single target was queued more than once (or "already") | |
| 15. This display made it easy to queue targets. | 5.06 |
| Too many screens to accomplish a similar and simple action | |
| 16. I was able to manipulate the RSTA images effectively. | 5.08 |

Teleoperation

| | |
|--|----------------|
| 6. The streaming video was sufficient to allow me to teleoperate the XUV. | Rating 4.97 |
| Yes, but... had to get very close to inspect images to ID | |
| 7. I used the map display while teleoperating an XUV to help me maintain the location of an XUV. | 6.33 |
| Mainly just starting and stopping | |
| 8. There was a significant time delay that made controlling the XUV difficult. | 4.35 |
| Turning seems a little slow | |
| 9. The button labels accurately represented the buttons' functionality. | 5.67 |
| 10. I found the Teleoperation display easy to use to control XUVs. | 4.72 |

Reporting

| | |
|---|----------------|
| 9. The button labels accurately represented the buttons' functionality. | Rating 5.83 |
| Though the button path to report seems long | |
| Much had no bearing on tasks of testing | |

| | |
|---|------|
| 10. Much of the information presented on the display was NOT helpful. | 4.44 |
| At least to my needs of the experiment | |
| 11. I sometimes felt 'lost' navigating the reporting display screens. | 3.39 |
| Color coding the buttons may help | |
| Especially at first, recommend simplifying submitting a report or make it the same for both RSTA & Teleop | |
| 12. There was not enough information displayed on the reporting screen. | 2.42 |
| 13. Composing a SPOT report was an easy task to accomplish. | 5.94 |
| After practice, yes, but should try to keep it the same for both RSTA & Teleop | |
| Very quick... block on repeat usage of status was odd... | |
| 14. Composing a SPOT report took too long to accomplish. | 3.5 |
| At least when operating gunner also | |
| 15. The entry fields for composing a SPOT report were found in the order I expected them to be. | 4.93 |
| Should try to keep them together, or in order of use | |
| Vertical flat panel wants two hands for rapid typing | |
| 16. Using the reporting display to compose reports was an easy process overall. | 4.94 |
| After practice, yes | |

General Usability- RCTA OCU

| | |
|--|----------------|
| 18. The touchscreen buttons were large enough to use effectively. | Rating 6.06 |
| 19. The print/ text on the OCU soft buttons was clear, and easy to read. | 6.11 |
| 20. It was easy to learn to use the basic features of the OCU. | 5.5 |
| 21. There are <u>not</u> enough displays to accomplish the required tasks. | 2.81 |
| 22. The point at which my finger touches is not identical to the point indicated by the touchscreen (there are parallax problems). | 2.75 |
| 23. Throughout the OCU, the same terminology is used to indicate the same information. | 4.89 |
| Double "click" of chip select sometimes irritating | 3.44 |
| 24. I sometimes feel "lost" when working with the OCU. | |
| At first | |
| Associate double click of "Get Mosaic" or "Get Snapshot" seemed to break things | |
| 25. I had a hard time finding information I needed on the OCU. | Rating 3.14 |
| There are a lot of displays | |
| 26. It was easy to understand what the icons used on the OCU displays represented. | 4.94 |
| 27. The OCU gives appropriate warning messages when I am about to make a serious mistake. | 2.83 |
| Never encountered any | |
| Hit wrong button clears easily by hitting right button | |

| | |
|---|------|
| 28. With the OCU, if I make a mistake I can correct it easily. | 4.38 |
| 29. It is obvious which command button brings up the OCU display I need next. | 4.72 |
| Except when generating a report, then you need multiple displays | |
| 30. Information is appropriately arranged on the OCU displays. | 4.97 |
| 31. Color-coding on the OCU displays is helpful. | 5.53 |
| “Selected” color change- informative but not emphatic | |
| 32. The symbols that were used were hard to learn. | 2.72 |
| 33. Overall, I think the OCU was easy to learn. | 5.11 |
| Took awhile, and lots of errors | |
| 34. Overall, I think the OCU was easy to work with. | 5.28 |
| Graying out buttons that aren’t useful at the moment can be helpful, e.g., “execute plan” button after the XUV is started | |
| Yes, after the steep learning curve it was | |

General Comments:

- Group execute button near snapshot & grab mosaic
- Automate labeling
- Gray out buttons that are not necessary for a particular function
- RSTA scan - after queue, provide pop up menu to label and report on RSTA screen instead of switching to map
- Same for reports - should not have to switch to report display
- Teleop - better resolution

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Glossary of Acronyms

| | |
|-------|--|
| ANOVA | analysis of variance |
| ARL | Army Research Laboratory |
| ATR | aided target recognition |
| BLOS | beyond-line-of-sight |
| CCT | Cube Comparison Test |
| FCS | Future Combat System |
| LOS | line-of-sight |
| LSD | Least Significant Difference |
| MCS | Mounted Combat System |
| OCU | operator control unit |
| OTW | out-the-window |
| PAC | perceived attentional control |
| RCTA | Robotics Collaborative Technology Alliance |
| RSTA | Reconnaissance, Surveillance, and Target Acquisition |
| SA | situational awareness |
| SIL | System Integration Laboratory |
| SNR | signal-to-noise ratio |
| SOT | Spatial Orientation Test |
| SpA | spatial ability |
| SSQ | Simulator Sickness Questionnaire |
| TCU | Tactical Control Unit |
| TS | total severity |
| TSS | Total Severity Score |
| UCD | unmanned combat demonstration |
| UGV | unmanned ground vehicle |
| XUV | eXperimental unmanned vehicle |

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